

WITH THE AUTHOR'S COMPLIMENTS

THE APPLICATION OF THE RÖNTGEN RAYS IN  
THE MEDICAL AND SURGICAL DEPARTMENTS  
OF THE ROYAL INFIRMARY, GLASGOW

BY

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# THE APPLICATION OF THE RÖNTGEN RAYS IN THE MEDICAL AND SURGICAL DEPARTMENTS OF THE ROYAL INFIRMARY, GLASGOW.\*

By JOHN MACINTYRE, M.B., C.M., F.R.S.E., F.R.M.S.

## INTRODUCTION.

THE experiments recorded in the following pages were begun towards the end of January, 1896, within seven weeks of the publication of Professor Röntgen's classical paper, which was read before the Würzburg Physical Society on November 24th, 1895. The results were sufficiently promising to induce me to request the managers of the Royal Infirmary to form a new branch of the electrical department of the hospital. This proposal was carried into effect towards the end of February of the same year, and Drs. Archibald Faulds and George M'Intyre were appointed assistants in the electrical department, the latter to devote himself more particularly to the medical cases, the former to look after the surgical. Since then these gentlemen have rendered great assistance to members of the staff in their respective spheres, not only in connection with the X rays, but generally in the medical and surgical electrical appliances of the hospital, and I have much pleasure in tendering my thanks to them for the time spent and labour expended in the performance of their duties.

Any one who took the trouble of reading Professor Röntgen's original work, could not fail to appreciate the value of direct inspection of the tissues of the body, as revealed by the fluorescent screen. It need hardly be pointed out, however,

\* Reprinted from the *Glasgow Hospital Reports*, 1898.

that the photographie aspect of the question was first of all seized upon and practically to the exclusion of the other. As the art progressed, however, it became more and more apparent that while photography might be useful by way of permanent records, direct vision would in all probability become the more important of the two. Viewed from the knowledge of the present day, considering that Professor Röntgen's great discovery was first made by what he *saw* upon the fluorescent screen, and that photography was a secondary detail, it is somewhat interesting to look back upon the claims for advances and discoveries put forward by many within a short period of the publication of the original paper. This remark is made, firstly, because the experimental work in the Royal Infirmary has convinced me of the great value to be attached to the whole of Professor Röntgen's original work; and, secondly, because I desire it to be clearly understood that the entire credit of observation by direct vision and photography is due to Professor Röntgen, and to him alone. All that the original discoverer left for any one else to do was improvement in apparatus and practical application.

While this much may be said, it is only fair to state that for many reasons the photographie art was the first and the more easily developed. Step by step with the advancement of the photographie art, improvements were however made in fluorescent screens, and if this method has developed more slowly than the other, its value is steadily increasing.

#### APPARATUS.

Speaking generally, it may be said that the supply of electricity from the mains gives the most satisfactory results.

**Source of the Current.** In the Glasgow Royal Infirmary the installation includes gas engine, dynamo, and secondary cells, and the whole house is wired for a fifty volt system. Where heavy currents are required, say for the cautery, much heavier leads are taken to the instrument; and in the case of X ray work, as presently used, twenty to twenty-

five amperes may be required for the coil. Primary batteries we have discarded altogether. It has to be admitted, however, as we found by experiment, that currents from large

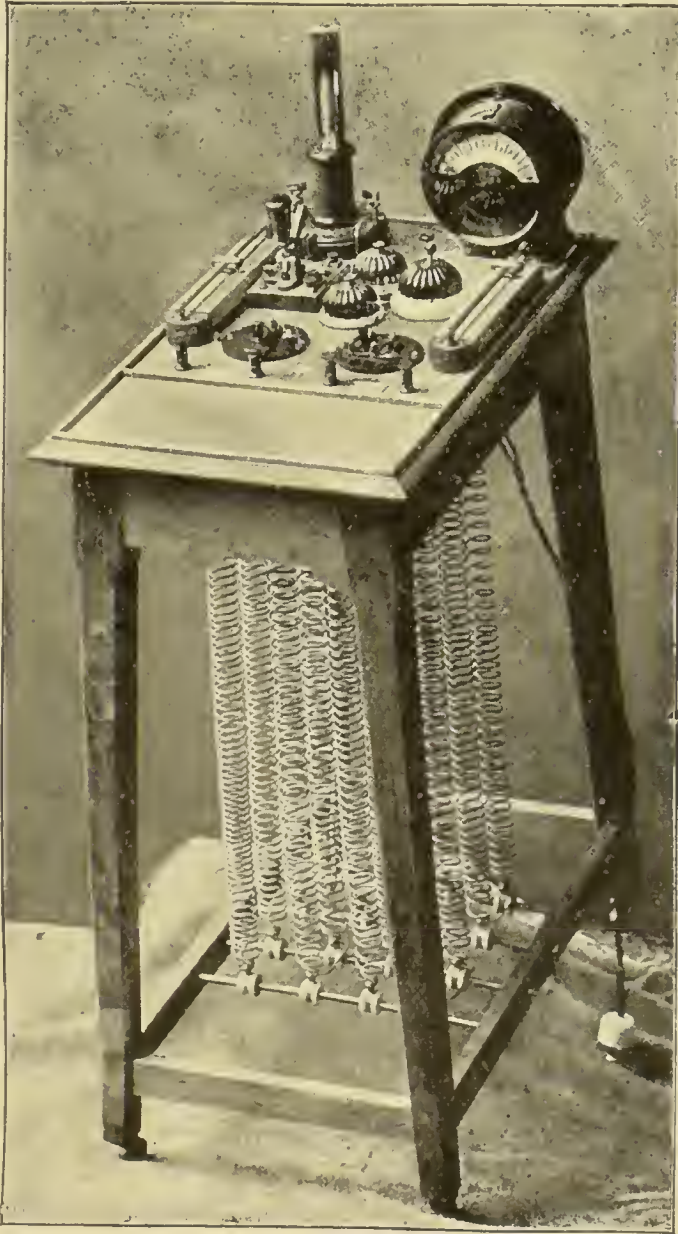


FIG. 1.—PORTABLE STAND FOR RHEOSTAT METERS USED IN X RAY WORK.

secondary cells, such as we use for surgical electrical purposes, are apt to cause severe sparking across the platinum points of the interrupter, with the result, as it is hardly necessary to point out, that there is a considerable decrease in the working



efficiency of the coil. Under these circumstances, Drs. Faulds and George McIntyre have frequently used smaller secondary cells charged from the dynamo, and made by the Litanode Company, London.

The above-mentioned difficulty may be overcome in more ways than one, but the most common is the employment of rheostats properly arranged. Figure 1 **Rheostats.** shows a portable rheostat designed by the writer, and employed in the hospital for such work. It consists essentially of a portable table below which, by means of proper platinoid wires attached to various studs, resistance may be thrown in as desired. On the same table an ampere meter and a galvanometer may be placed, so that exact measurements for the particular coil may be estimated. There is one drawback, however, to this resistance, that while we are able to vary the amperes of current the voltage is not taken into account.

At my request, therefore, Mr. Schall, of London, has constructed another rheostat as seen in Figure 2. By means of this new arrangement not only can we vary the number of amperes, but the number of volts can also be controlled by the operator.

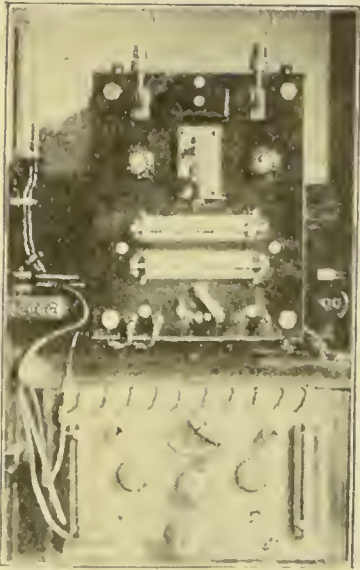


FIG. 2.—X RAY RHEOSTAT FOR VARYING VOLTS AND AMPERES.

The principle of this rheostat may be briefly described in the following way: The current from the mains passes directly through a stout platinoid wire as soon as the switch on the rheostat is turned on, the resistance being 4 ohms, and the diameter of the platinoid wire sufficient to allow of 25 amperes to pass without getting hot. The current which is to pass through the primary of the spark coil is obtained by tapping the above-mentioned platinoid wire at suitable places to obtain the desired voltage. If we take the two ends of a line and mark them *A* and *B*, and another point in that line and call it *C*, then if we tap it at two places, say *A* and *C*, the

electromotive force of the shunt circuit depends upon the difference of the resistance between  $AC$  and  $AB$ ; making  $C$  variable, we can vary the electromotive force of the shunt circuit to suit the special purpose. If the coil be connected to  $A$  and  $C$  there are two ways open to the current, one through the platinoid wires of the rheostat, and the other through the thick primary wire of the coil. The current will divide itself between these two loops in proportion to the resistance it finds on the way. To facilitate a perfect control, a small rheostat with a variable resistance is inserted in this shunt circuit, so that the proportion can be conveniently varied. In my rheostat the current in the shunt circuit may be varied between 5 amperes and 25 amperes. When the interrupter begins to vibrate, the current is shunted; while the interrupter makes contact, it passes through the primary of the spark coil; while it breaks the contact, it passes through the platinoid wires of the rheostat. The current from the main is never broken, it is only being shunted in other channels, the consequence being that the sparks at the platinum points of the interrupter (which are so strong under ordinary circumstances that the platinum has to be renewed fairly frequently) are scarcely perceptible with this shunt arrangement.

The advantages of this rheostat are very great, because we can arrange the number of volts and the number of amperes for any size of coil from the two to the eighteen inches spark. My work has not only been greatly facilitated by means of this new arrangement, but sparking across the platinum points of the contact breaker has been diminished, and the risks to the Crookes' tubes have been considerably lessened, while the steadiness and constancy of current have been assured—matters of great importance, as any fall in either ampereage or voltage as indicated on the meters can be instantly corrected by the operator.

The most of the experimental work in this hospital has been done by means of one of Apps-Newton coils of ten inches spark, and within certain limits this may be considered an excellent instrument. I have had many opportunities of testing coils from two to eighteen inches spark of the Apps-Newton pattern, and in no

**Transformers, etc.**

case have I found one which did not fulfil all that was expected of it. As a rule, they are found to do better work than the makers claim for each size. Most of my work in connection with the deep-seated parts and soft tissues of the body has been done by these coils ranging from ten to eighteen inches spark, and my latest experimental work in instantaneous X ray photography and cinematographic records to show movements within bodies has been done with the large-sized coil, which I have found to be in every way reliable. It is only fair to say, however, that the earliest work was done with a large German coil (Figure 3), giving also ten inches spark.

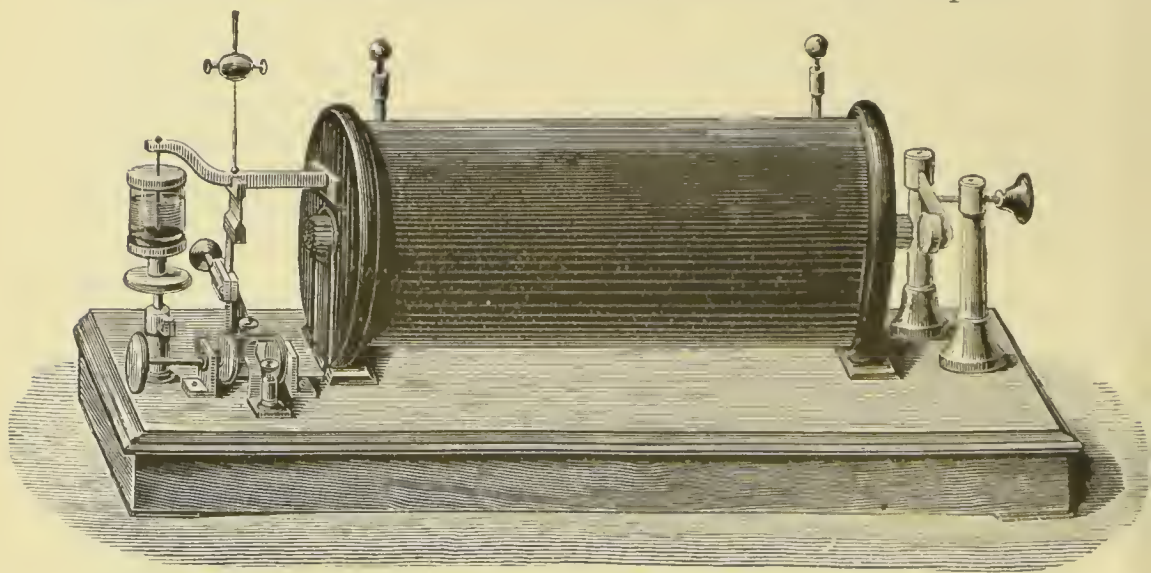


FIG. 3.—GERMAN COIL, PLATINUM AND MERCURY INTERRUPTERS.

Our experiments, however, have included tests by means of the induction coil combined with the Tesla; secondly, as indicated above, by means of the ordinary induction coil alone: and lastly, by means of an influence machine of the Wimshurst pattern, each method having its advantages as well as its disadvantages.

In Figure 4 will be seen the earliest apparatus with which I took a photograph by means of the X rays. It consists essentially of secondary batteries, a six inches spark induction coil, suitable Tesla apparatus (see Figure 5), and a Crookes' tube.

As far as our work was concerned this was discarded in favour of the simpler arrangement of the induction coil alone, but our earliest experiments suggested that this arrangement was not one to be set aside altogether in favour of what is



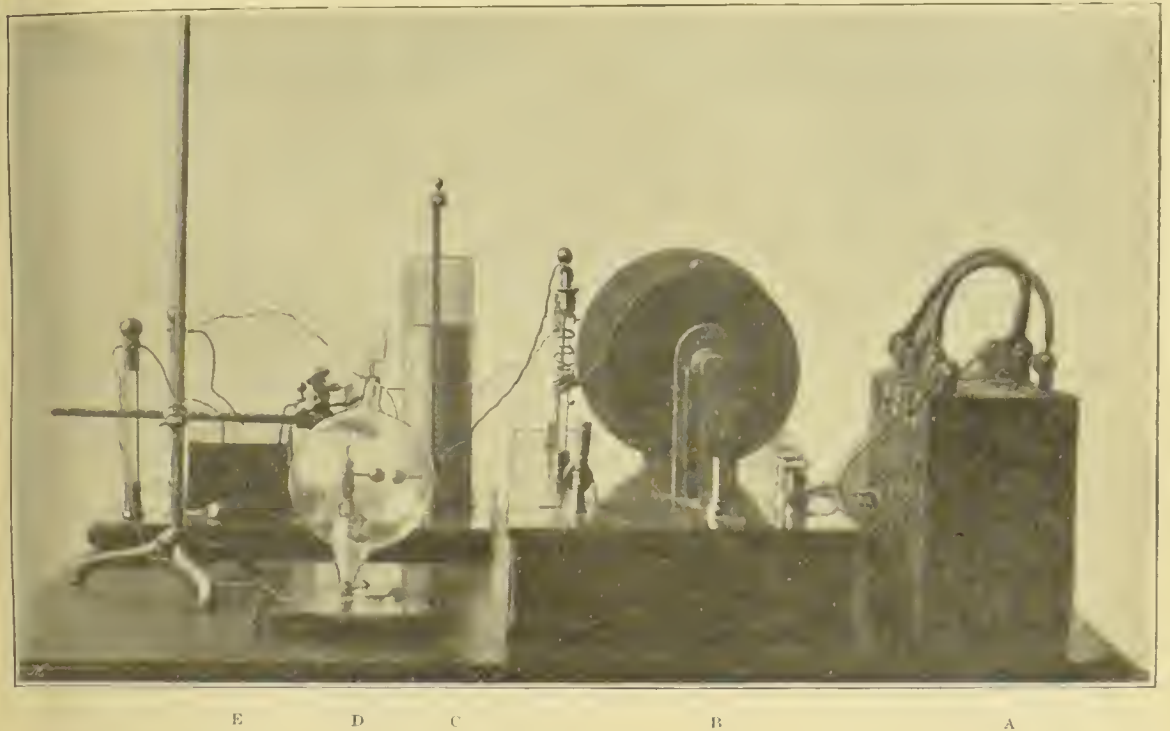


FIG. 4.—FIRST SET X RAY APPARATUS EMPLOYED—CONDUCTION COIL COMBINED WITH TESLA. A, Battery; B, induction coil; C, Tesla; D, Crookes' tube; E, dark camera slide with plate inside, with objects to be photographed on top.

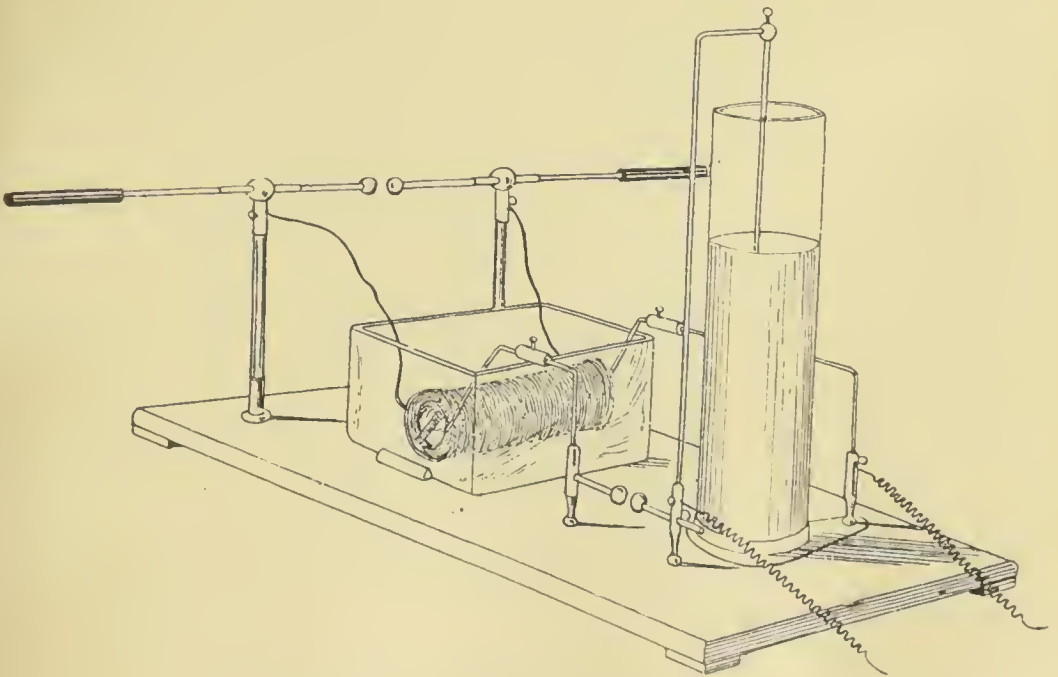


FIG. 5.—TESLA COIL EMPLOYED (Baird & Tatlock).

now the common method. For example, from experiments which I have had an opportunity of performing elsewhere, I am forced to the conclusion that, while it would be impossible to agree altogether with the statement that where the alternating current instead of the continuous is at our disposal, suitable Tesla transformers may altogether displace the more common induction coil, yet more will likely in the future be said on this point. This idea is still further strengthened by a consideration of the most recent improvements in Tesla apparatus. Professor Sylvanus Thomson, of London, favoured me with a demonstration of one of Tesla's new instruments for the production of oscillatory discharges. For this high frequency discharge, Mr. Tesla has further designed special tubes with striking results. This new apparatus, as Professor Sylvanus Thomson very properly puts it in the introduction of his presidential address to the Röntgen Society, gives us a new kind of induction coil based upon the principle of resonance, by which, without any energy-wasting spark-gap, and by the use of relatively few turns of wire, one can take the current straight from the electrical supply mains and transform it into high frequency discharges. It will be noted in the last-mentioned statement we are here dealing with an apparatus of Tesla's which does not require an alternating circuit. I am at present engaged in investigating this question, and everything goes to show that for medical and surgical purposes we have by no means reached the perfect instrument in the ordinary induction coil, but more than this one cannot at present say. The third means of exciting the Crookes' tube is by means of the influence machine, of which there are many designs in the market, but probably none better than that made by Mr. Wimshurst.

Figure 6 shows one of these machines made by Mr. Wimshurst, and now in my possession. This subject will be referred to further on when we are speaking about the results which have been obtained during our experiments. A large number of tests has convinced me, however, that for practical purposes we should not have a machine with fewer than eight plates of about eighteen inches in diameter. The instrument above figured is, next to Lord Blythwood's, the largest machine

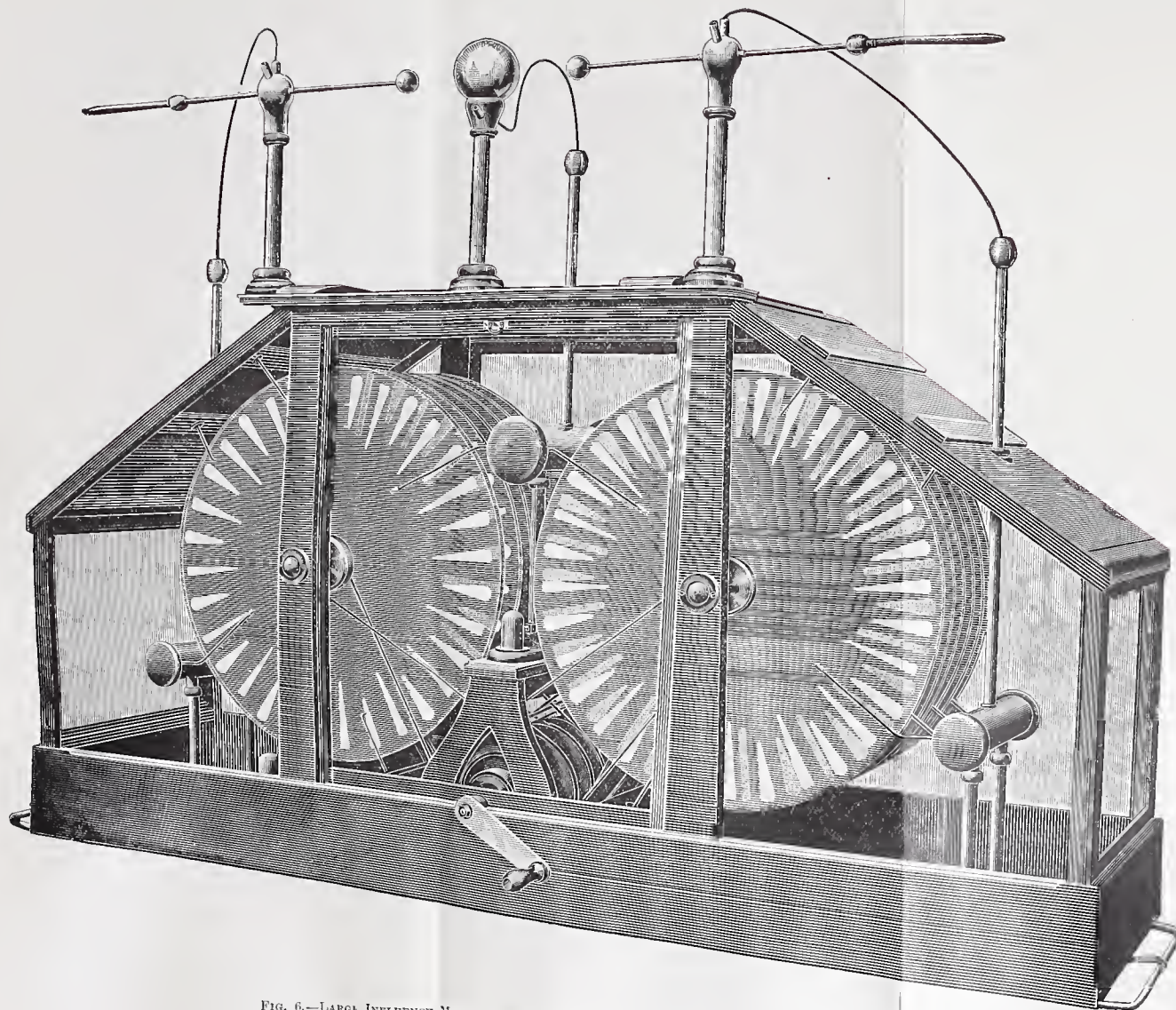


FIG. 6.—LARGE INFLUENCE MACHINE EMPLOYED IN X RAY EXPERIMENTS. Made by Mr. Winshurst.







hitherto constructed. It consists of twenty-four plates, each thirty-six inches in diameter, and is driven by an electro-motor. The great advantage which has been claimed for such an instrument is steadiness of illumination in screen work. Notwithstanding a great many experiments which I have tried with a view to doing away with the flickering, there is always a certain amount present with the coil. The influence machine in that respect at least is a distinct advantage. Mr. Wimshurst has assured me from his standpoint that the influence machine has not been thoroughly appreciated, and this has probably been the result of the general impression that the instrument is more useful for fluorescent screen work than photography. My more recent experiments, however, have caused me to doubt this statement, and the subject will also be referred to further on in the paper.

A large number of experiments early convinced me that some improvements would ultimately require to be made in the contact breaker of the coil, particularly when dealing with large sizes. The ordinary spring **Interrupters.** interrupter, which is supplied with coils, I found very good for photographs of the bones, and particularly those of the extremities; but when experiments led us in the direction of the deep-seated tissues, it was found that the range of which it was capable did not suit our requirements. The first observation which led me to investigate this point more particularly was the fact that in the large German coils to which a mercury interrupter was attached (see Figure 3), fluorescence as witnessed in the Crookes' tube was quite different from that obtained with the ordinary spring interrupter, which was also attached to the coil.

The subject was studied from the following standpoints: First, it was noted when using the mercury interrupter that the ampere meter registered a much higher current than when the ordinary interrupter was in use. Secondly, the spark across the discharge rods not only varied in length but in thickness, evidently in some proportion to the rise of current as indicated on the meter. Thirdly, photographs were obtained with much less time of exposure. Fourthly, the fluorescence screens were much more brilliantly illumined. Lastly, the Crookes'

tube itself was more powerfully excited. Each of these factors was taken into careful consideration, comparative tests were made on fluorescent screens and photographic plates, with the result that a considerable number of instantaneous photographs of certain parts of the body were obtained, while in the deeper seated structures more rapid results were got.

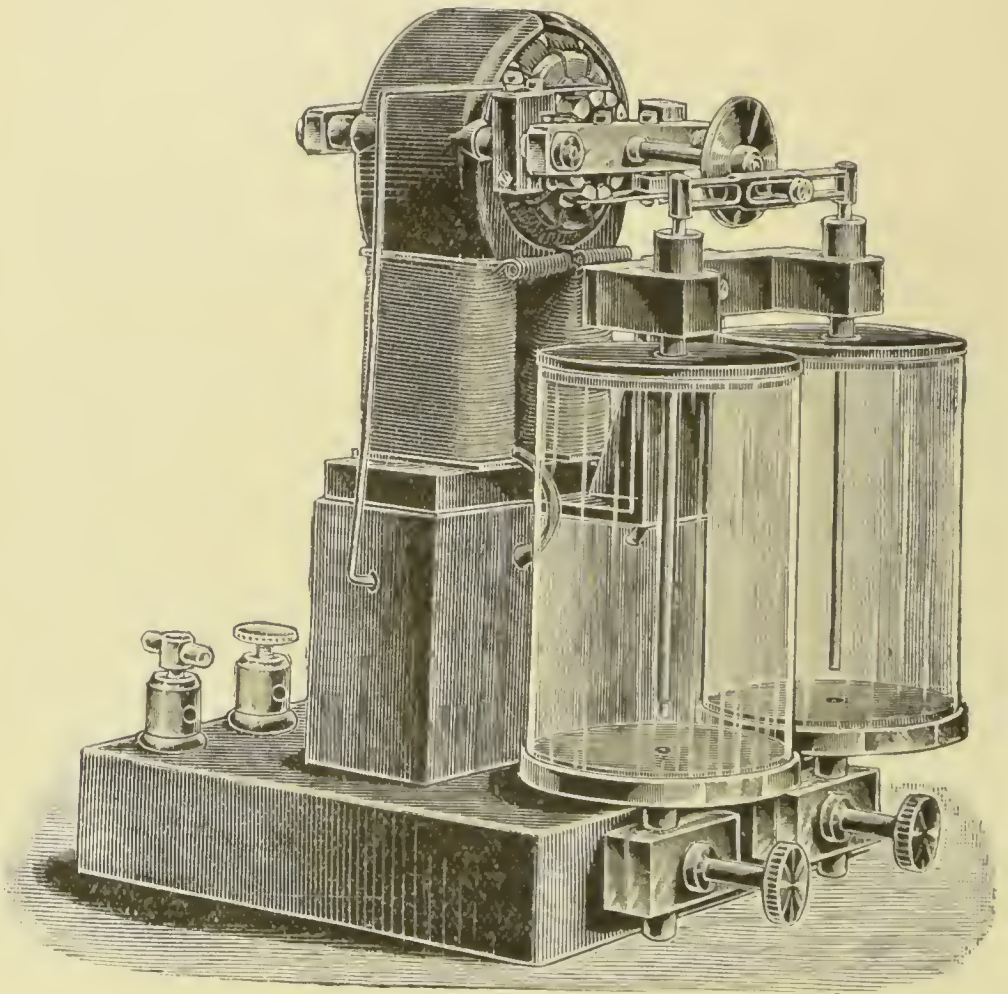


FIG. 7.—ROTATING MERCURY INTERRUPTER.

In Figure 7 will be seen another form of mercury interrupter, in which two platinum points are caused to dip in and out of mercury by the rotation of a wheel driven by a small electro-motor. This is an excellent instrument, and was supplied by Baird & Tatlock. All the mercury forms, however, have disadvantages, as the metal gets oxidised, although Mr. Apps has informed me (and I have tried the method) that an

amalgam of mercury and platinum prevents this to a large extent, particularly if a large quantity of alcohol be resting on the surface of the mercury. Under these conditions, sparking at the make and break of the point is very much reduced. With a view to obtaining still better results, and doing away as far as possible with the difficulties of the mercury interrupter, a mechanical form was made at my request by Mr. Apps. This will be seen in Figure 8. The instrument consists of a wheel driven by a motor, which causes a vertical arm to move laterally right and left. On each stud of the

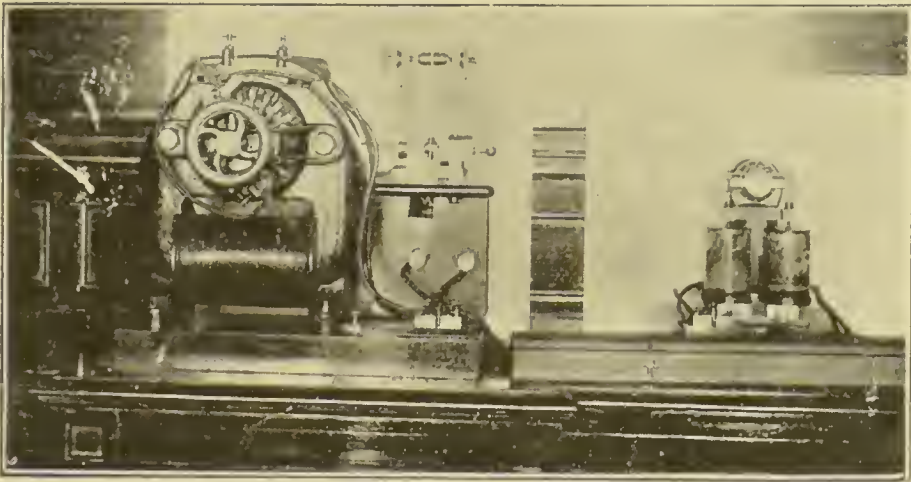


FIG. 8.—MECHANICAL AND MERCURY INTERRUPTERS.

arm we have platinum points, which come in contact with two corresponding platinum points on two upright metal arms. With each revolution of the wheel, therefore, two contacts are made. It will at once be seen that here we have a means of varying the frequency which depends upon the number of revolutions of the motor, and again by adjusting the platinum studs we can cause the points to remain in contact for a time. It will be found that when we adjust these studs by approximating them, so as to cause longer contact between the platinum points, the same thing occurs as with the mercury interrupter, viz. there is increase in the current passing to the coil as indicated on the ampere meter, sparks are thicker, the tube becomes more brilliantly illumined, and the fluorescent screen is correspondingly increased



in brilliancy. By this instrument we have gained the advantages therefore (1) of the regulation of the number of makes and breaks per minute, (2) of allowing the contact to be as long or as short as we please, thereby giving the primary coil a thorough charge before the current is broken, and (3) by this means we can measure the actual time that the platinum points are in contact during say a second or a minute's exposure, and so in repeating experiments uniformity may be obtained. I have also had an opportunity of testing Watson's "Vrill" interrupter, which is a good instrument.

It may at once be said frankly that the focus tube, to which the profession is indebted for selection to Mr. Herbert Jackson, is the one used in the hospital. Many  
**Tubes.** forms of it have been tried. The penetrator, as recommended by Watson, is good. A large number have been

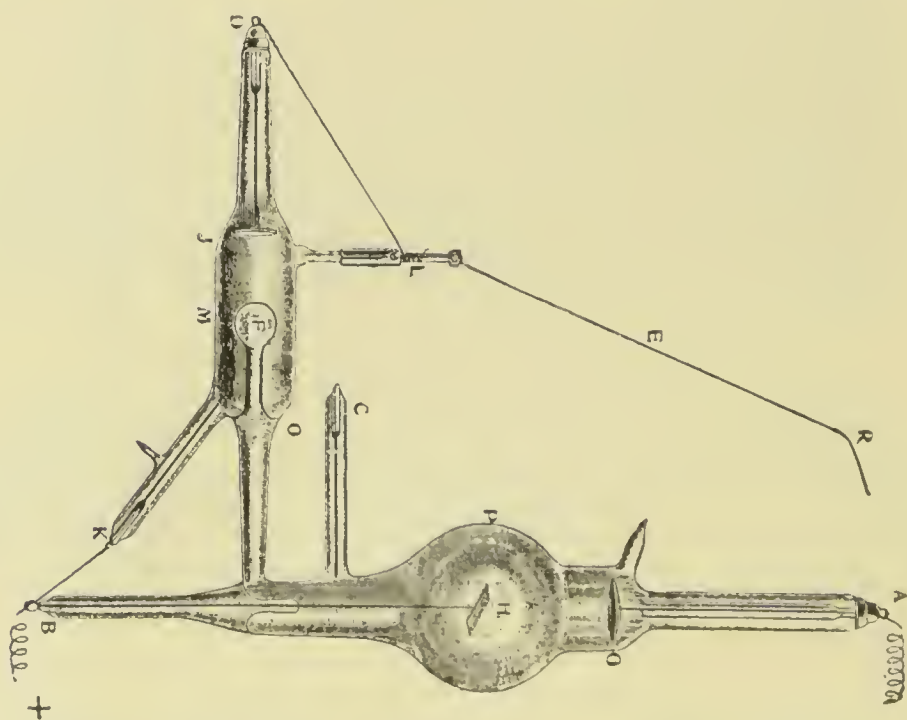


FIG. 9.—QUEEN'S TUBE. +, —, Positive and negative wires; n, anti-cathode; o, cathode; F, inner bulb containing chemical substances; J, M, lesser bulb; E, R, bridge adjustable for distance between R and A.

supplied by the General Electrical Co. The only novelty of late has been one or two tubes of Queen & Co., Philadelphia. This is a modification of the focus tube as represented in Figure 9. The principle may be described by saying that in



the small bulb a certain chemical is given off when heated, and it is again absorbed when the tube cools. The arm seen above is adjustable, so that a gap can be arranged between  $g$  and  $a$ . By this means the tube can be kept at a particular vacuum for any length of time, and the vacuum is kept constant, as the tube is self-regulating.

With regard to the practical use of the tube, it may here be stated that as a rule, with ordinary tubes at least, heating by means of the Bunsen or spirit lamp is the plan adopted when the vacuum gets too high. I have also made use of Mr. Wimshurst's suggestion, to place a piece of tinfoil or gold paint round the neck of the tube. This to a large extent does away with the necessity of heating, and to a very considerable extent regulates the vacuum.

Notwithstanding the above statement, however, I think in order to get the very best results the vacuum of the tube ought to be regulated for the particular coil in question. In designing the tubes I paid special attention, first, to the fact that the tube is very long in measurement, eighteen inches at least in its long diameter. This prevents sparking across the outside surface of the glass, although as the vacuum rises it probably increases the risk of injury to the tube. Secondly, the discs passing into the tube are very thick. Thirdly, as described in a paper to the *Lancet*, in the early part of 1896, I made the anodes adjustable, so that we may find the exact point at which the best result is obtained. Mr. Campbell Swinton makes the cathode adjustable, and I have found it useful to take advantage of another suggestion by this gentleman, namely, to embed the platinum of the anti-cathode in a thick block of aluminium; this prevents heating. There is no detail of too little importance to be attended to. For example, the glass (German) must be thick enough to allow of heating, and yet not too thick to obstruct the passage of the rays. Figure 10 shows the design of the pump, for many details of which I am indebted to Dr. Bottomley, who was good enough to give Mr. Otto Müller, who made it, many suggestions, the result of his own experience.

As indicated above, the voltmeter and ampere meter should

always be in the circuit. Lord Kelvin's meters are excellent and reliable, while Newton has devised a cheaper instrument which combines both measurement of volts and amperes in one. This I have also used with advantage.

**Accessories.**

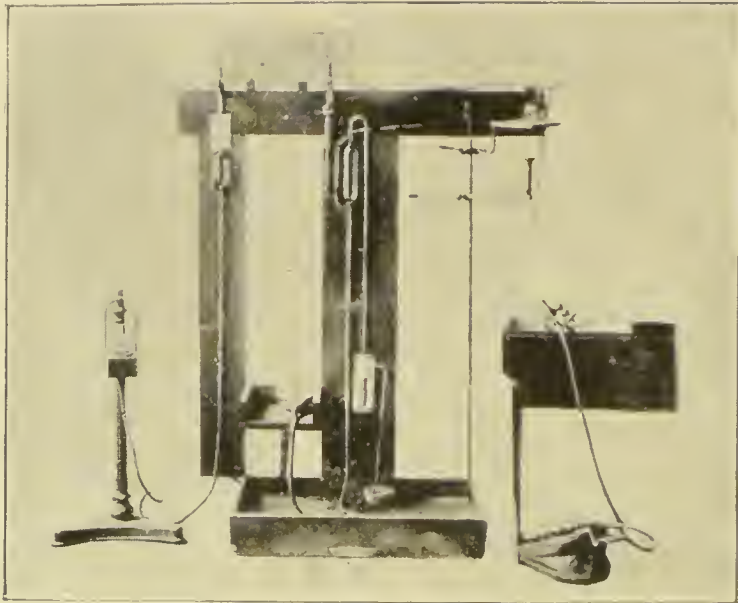


FIG. 10.—MERCURY PUMP FOR EXHAUSTING CROOKES' TUBES.

Several of these are in the market, the best being one of calcium tungstate as supplied to us by Schall. Where quick exposure is required it is useful, but owing to the grain of the salt which appears on the plate our experience is to discard it, and particularly in instances where a well-defined photograph is required. Speaking generally, we may say that the use of the cryptoscope has been discarded for the dark room. Our best effects on screen-work have been obtained by causing the room to be made absolutely dark, and I have designed a special stand for holding the Crookes' tube, and enclosing it in dark cloth, so that even the light of the tube itself is excluded.

**Intensifying Screens.**

Experiments have been tried with a large number of fluorescent salts; amongst others may be noted barium-platino-cyanide, potassium-platino-cyanide, lithium-rubidium-platino-cyanide, calcium tungstate, schaelite, urynal fluoride. Specimens of these screens have been made by myself, and afterwards with a

**Fluorescent Screens.**

view to testing more carefully, by Kahibaum, whose excellent materials are well known. No one who has worked with the potass salt, especially if it be hydrated, can doubt its superiority in fluorescence and definition; but the disadvantages are that the salt does not keep so well, and it is difficult to keep it hydrated. When we get really good specimens of the barium-platino-cyanide salt, it approaches very nearly to the potassium. Its advantage is its stability. Screens made of this material last for a long time, and when the salts have been carefully prepared originally, the screens stand a good deal of tear and wear. The story of the calcium tungstate is an interesting one. It may at once be said that after eighteen months' careful testing with the calcium tungstate material, prepared for me by many chemists on this side of the Atlantic, as well as specimens got from America, I have no hesitation in saying that the salt is distinctly inferior to the barium-platino-cyanide. It is true it is cheaper. In addition to its inferiority by way of fluorescence, an observer who has to examine a number of cases gets annoyed by the persistence of images. Mr. Edison was the first to recommend calcium tungstate, and his results were announced by cablegram some time after we had made our earliest experiments in fluorescence in this hospital. A great deal was claimed for calcium tungstate, and subsequent writers, such as Dr. Morton, seemed to endorse the statements; nay, more, some did not hesitate to say that calcium tungstate, crystallized and specially prepared, gave six times better results than the barium salt. My only object in working with the X rays was, of course, to find out what would be most useful in the examination of medical and surgical cases; and, with such statements before me, I thought it my duty to have specimens of these salts prepared. Through the kindness of Dr. Frank Bottomley and Messrs. Baird & Tatlock, who prepared some crystalline material from the amorphous form, I had many specimens of these salts prepared. In no instance could I come to the conclusion that barium-platino-cyanide was inferior to calcium tungstate, and this notwithstanding the great authority who had recommended it. As this statement had been endorsed by Dr. Morton, of New York, one of the best known experts on the other side



of the Atlantic, I wrote explaining matters, and requesting him to furnish me with some specially prepared material, and likewise to choose the best fluorescent screen which he could obtain. This he kindly did, and I obtained them from Messrs. Jackson & Ailsbury, of New Jersey. A most careful series of tests led me again to the conclusion that the calcium tungstate salt was inferior. On the strength of these experiments, again I wrote to Dr. Morton who, in reply, was kind enough to inform me that he believed the erroneous impression of the extra value of calcium tungstate was due to those in America having had inferior specimens of barium-platino-cyanide. Although these statements appear in his book, he acknowledges now that they were the result of the earlier experiments, and he further informs me that the makers of screens, even in the United States, have found the calcium tungstate displaced by what we had from the first found best. Lithium-rubidium screens are also very good, but in my hands I have found nothing to recommend it over the barium-platino-cyanide. Urynal fluoride and calcium tungstate may be used with great advantage as intensifying screens to hasten the exposure, a matter of some importance where for any reason one does not wish to expose the patient to a prolonged sitting.

During the past two years many improvements have been made in the manufacture of screens, and, no doubt, those so commonly used and made by Kahlbaum are exceedingly serviceable. This chemist has succeeded in making the surface exceedingly smooth, but at the expense somewhat of sharp definition. To get the best results a great many experiments were performed with a view to discovering the exact size of crystal (say of the barium salt) which would be most efficient, and, generally speaking, it may be stated that within limits the coarser crystals are the better. When the barium-platino-cyanide salt is ground too finely a certain amount of effect is lost. Notwithstanding the various improvements, however, the ideal has yet to be got. It is quite evident, in the first instance, that we are utilizing nothing like the number of X rays which come from the focus tube in this work, and probably the same remark is quite correct if applied to photography as well. I have placed four screens in





EXPERIMENTS IN SOFT TISSUES,—NORMAL HEART.

First Photograph of this Organ.



front of each other at a distance of one foot apart, and found that the last one was sufficiently illuminated to show the bones of the hand quite distinctly. Experiments were tried to stop more of the rays by increasing the thickness of the layer of crystals on the screen, but still the majority seemed to be passing straight through, and naturally there must be a limit to these experiments, because after certain thickness the image becomes very indistinct. For sharp definition I have never seen anything equal to the hydrated potassium-platino-cyanide screen.

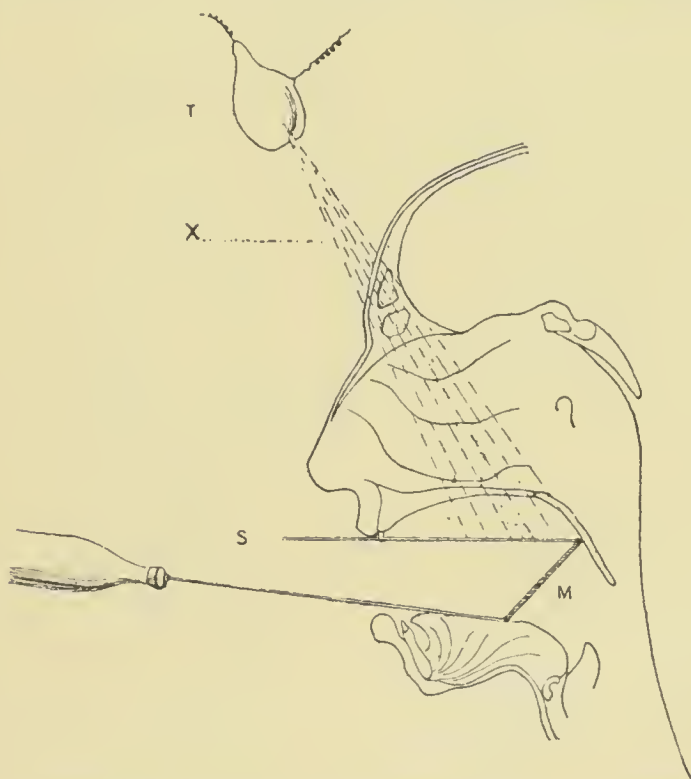


FIG 11.—METHOD OF EXAMINING WITH SCREEN IN MOUTH. T, Crookes tube; M, ordinary laryngeal mirror; X, Röntgen rays; S, screen.

Screens may also be utilized in different cavities of the body. For example, I have designed a screen for the examination of the hard and soft tissues in the region of the bones of the face, and also those in the region of the neck and larynx. Figures 11 and 12 will explain these.

Briefly stated, they may be described as follows:—The fluorescent screen is placed inside the mouth and the lamp outside. Small discs of glass are coated with the salt and covered with aluminium; or, again, tongue depressors consisting

of flat strips of glass covered and coated in the same way may be employed. By placing the tube outside I am able to get an image of the septum and other parts of the cavity of the nose on the fluorescent screen in the mouth. In the same way the roots of the teeth may be seen. If the surgeon desire to examine the parts below or above the jaws, he simply puts the Crookes' tube below or above and passes the rays through

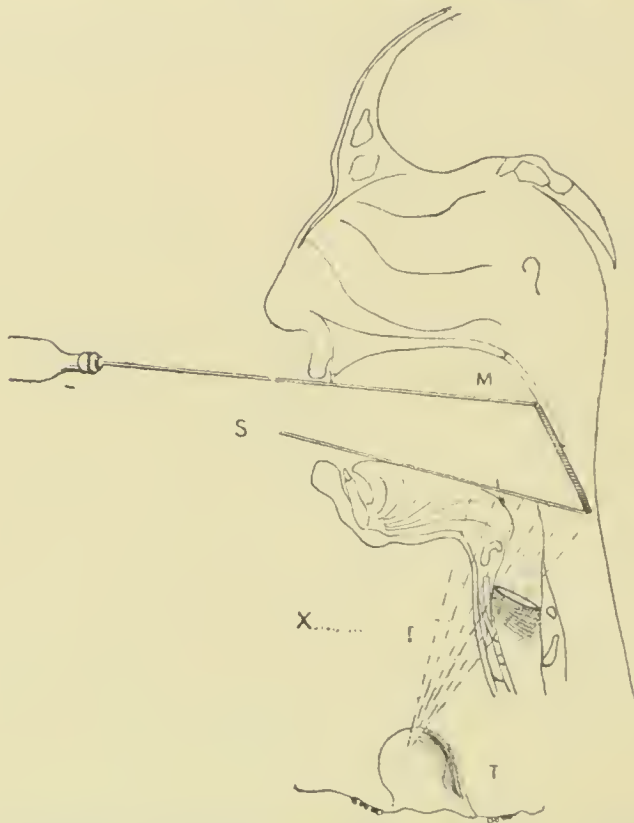


FIG. 12.—METHOD OF EXAMINING WITH SCREEN IN MOUTH. T, Crookes' tube; M, ordinary laryngeal mirror; X, Röntgen rays; S, screen.

the tissues. If he desire to examine the tissues externally that is to say, to pass the current through the neck, he places a small fluorescent screen on one side and removes the Crookes' tube to a suitable distance. By this means I have been able to demonstrate the presence of foreign bodies, and need hardly add they are more easily photographed.

In Figure 13 will be seen a stand designed by me, and made by Messrs. Baird & Tatlock, for holding Crookes' tubes. It is six feet high, and has two non-conducting arms on which rest the wires coming from the coil. Its principle is simply that of the ordinary chemical stand, but I

#### Accessories.



have found it most useful whether for photographic purposes or for examination by means of the fluorescent screen. By the universal movements at our disposal we can arrange the tube for any part of the body, whether the patient be standing or lying down.

The condenser is a very important part of the apparatus, and while it is usually placed in the

#### Condensers.

base of the coil, it may be kept separate. As it is exceedingly important that the make and break of the current should be sudden, this part of the apparatus aids by preventing the spark of the extra current, due to self-induction in the primary circuit, passing across the interrupter. I have more than once found, when it was a little difficult to work, that something was wrong with the condenser, and there are times when it is advisable to have extra condensers in case of injury to the one in the base of the coil.

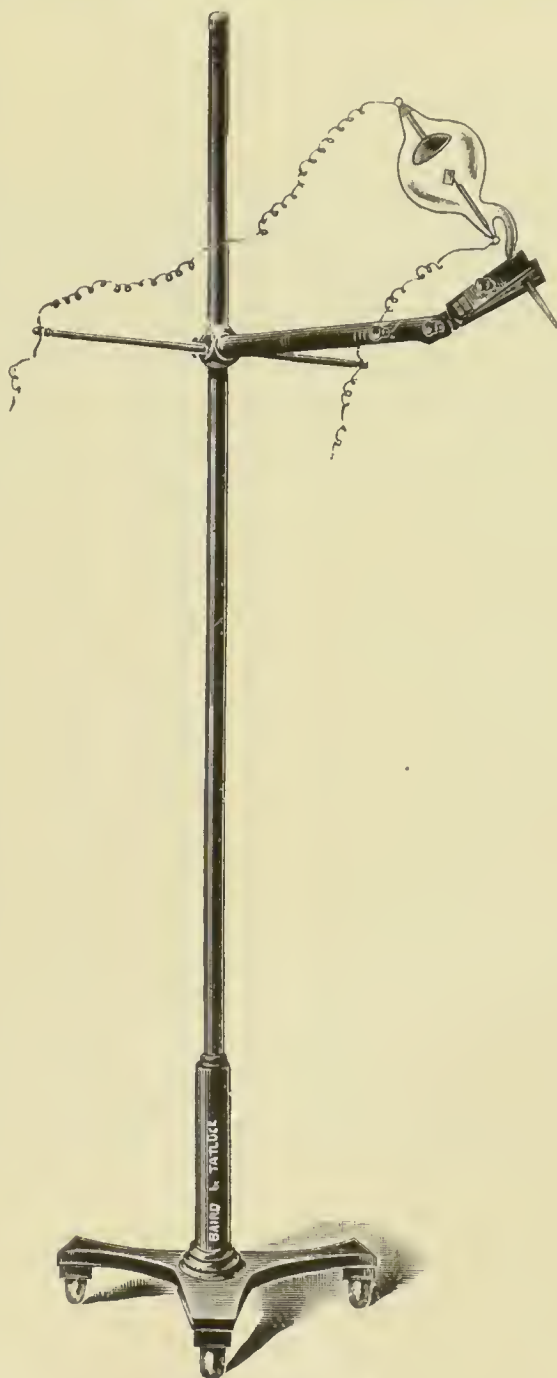


FIG. 13.—X RAY STAND (Macintyre).

## APPLICATION OF THE RAYS.

From my first experiments I have steadily insisted upon the careful appreciation of three different factors in order to get good pictures or shadows on screen: firstly, definition; secondly, penetration; and, thirdly, arrangements for selecting particular tissues or parts of the body. By this last statement I mean that sometimes it may be desired to photograph a particular object in the body and to omit parts which lie in front or behind it. Take, for example, the case of the heart. We may wish to photograph the heart without showing the sternum and ribs, or, on the other hand, we may wish to photograph the heart or an aneurysm without seeing the spine.

**General Considerations.** With regard to the first, viz. definition, it has been clearly enough established that the rays proceed somewhat in the form of a cone, the apex of which is at the anti-cathode within the tube. It naturally follows that, if the object be removed from the plate, ill-defined shadows will be obtained, and generally speaking, therefore, it is desirable to have the object as near the plate or screen as possible. The converse also holds good, because, where we have the object at some distance from the plate or fluorescent screen, the removal of the Crookes' tube to a greater distance improves the definition. That is to say, there is a relationship between the distance of the object from the plate or screen and the point at which the tube ought to be situated. Mr. Campbell Swinton has shown that the cone is hollow, but notwithstanding this fact the above statement within limits holds good. While it is not fair to say generally that the fluorescent screen is always a guide to what will take place on the photographic plate, nevertheless it is a useful rule to examine the part to be photographed first with the fluorescent screen. Generally speaking, the nearer the object to the plate, or, failing this, the further we can afford to remove the tube from the object, the better will be the definition. It is always to be remembered, however, that removal of the tube to a certain extent diminishes the power and lengthens the exposure. It is for this reason that I have



EXPERIMENTS WITH SOFT TISSUES OF NECK.—HUMAN LARYNX.





long advocated highly exhausted tubes to suit more powerful apparatus.

With regard to the second point, viz. penetration, it is useful to remember that the difficulties in getting through the thicker parts of the body are to be explained within limits by the fact that tissues oppose the rays according to their densities. As a result of careful experiments, I have come to the conclusion that when we have penetrated the tissues it does not take much to act upon the photographic plate or fluorescent screen. With my large coil and tubes in good working order I have had little difficulty in sending the rays through four persons (even six) standing in front of each other. I have likewise passed the rays seventeen feet across the room and through a large thick wooden partition in sufficient quantity to see shadows of the bones of a person's body who was standing inside one room while the observers were in the next chamber. I have also sent the rays over forty feet in air, then through the door in an adjoining building, and in sufficient quantity to show distinct fluorescence on the screen, although the rays had passed through the above mentioned wooden door, painted on both sides with lead paint. This great penetrative power is useful in the deeper seated tissues of the body—a fact which I have found of importance in taking more rapid photographs of the soft tissues of the body. In taking photographs in the deeper seated structures of the body, and more particularly when dealing with the hard and soft tissues, this is an important point for consideration.

There is yet another interesting point which it may be convenient to consider in connection with the above mentioned subjects, and that is localization of objects. In the early part of 1896 I conceived the idea of taking two images by means of two tubes, or by one tube first and then removing it to a distance. Two images were thus got on the screen or photographic plate. My friend, Mr. James Buchanan, M.A., of Peter's College, Cambridge, worked this out mathematically at the end of April, 1896. Since then many other workers, such as Mr. Ernest Payne and Dr. Mackenzie Davidson, have described different apparatus by means of which calculations may be omitted, and there

**Localization  
of Objects.**

can be no doubt that surgeons can now have a very definite idea of the exact localization of a particular object in the tissues.

I have also found the study of the appearances of the tissues at different conditions of the tube useful in attempting to photograph or see shadows of particular tissues of the body. For example, for the softer tissues which are less dense, the vacuum in the tube should be low. If, on the other hand, we wish to bring out the bones, one can, by raising the vacuum, get quicker and better results. Lastly, if it be a foreign body of dense structure, such as metals which are opaque to the rays, then a higher vacuum may become useful. These statements to a certain extent are merely generalizations, but modifications of the tube may be obtained for different densities of tissue. It is always necessary that the operator should define first of all what he desires to obtain. The regulation of the vacuum is of the utmost importance. Further, I have found two methods of advantage: firstly, either to keep a set of tubes at low, moderate, and high vacua, or, secondly, to use one of Queen's tubes, as described in a former part of this paper, whereby the vacuum may be varied and kept the same throughout an exposure. The disadvantage of the latter is the expense of the tubes.

In a certain number of cases it is possible to get the camera in front of the fluorescent screen and to take impressions of what is seen. This at present only applies to the extremities of the body, and its great disadvantage lies in the long exposures required. As a result of photographing with a number of different screens, I may say that I have found the potassium-platino-cyanide to be most useful owing to the blue colour and great actinic power. When this is done the operator must place a sheet of lead perforated for the lens in front of the camera large enough to cover the front, otherwise there would not only be a reduced image of the fluorescent screen, but also an enlarged image of the lens in front of the camera caused by the rays passing through the front of the apparatus itself. This

**Different  
Conditions of  
the Tube in  
the Hard and  
Soft Tissues.**

**Photographs  
of the Fluor-  
escent Screen  
itself by  
means of the  
Camera.**

method has its many disadvantages, but if it could be further cultivated it would certainly be desirable, as we could at once reduce pictures from life-size to small dimensions—a fact which is not only of great importance in saving material, but condensed pictures give sharper definition. Even a diffused round shadow of a coin in the body becomes a well-defined disc when reduced from 15 by 12 to lantern slide size, or quarter plate.

This apparatus is intended to enable one to test and compare the intensity of the focus tubes and the sensitiveness of fluorescent screens. I have found the apparatus useful, and, briefly described, it consists of a **Actinometer (Schall)** polished mahogany case, in the interior of which are twelve squares of tinfoil of various thickness, each square being provided with a lead figure. These are numbered from eight to thirty or more, if specially made. By simply looking through this meter one can get a fair idea of penetration and likewise of the sensitiveness of a particular screen.

With regard to photographic material, the majority of my experiments have been done with the Paget 50 plates. Lumière's have been tried, and also several plates sent by the General Electric Company, Berlin. **Photo-graphic Material, etc.** While I am not desirous in the least to minimize the advantages of quick photographic plates, or those of thick coating as recommended by Oliver Lodge, or double coating on both sides of the glass as recommended by others, nevertheless we have found a good Paget 50 plate very useful, and my experience has been that these plates are very constant and reliable. Moreover, I have paid more attention to the condition of the tube. The sensitive papers recommended by Eastman have also proved useful in some cases. Surgically speaking, it has been found of advantage in some instances to place a piece of sensitized paper on the top of the negative, the latter being reserved for a permanent impression, while the paper may be at once developed, if required by the surgeon for immediate apparatus. For the most part hydro-kynone and pyro have been our developing solutions.

In order to facilitate the work it is necessary that the



apparatus should be arranged so that every part is under control. Further, suppose a number of experiments have to be tried in succession, say where we wish to compare the results in different photographs, every factor should be kept as nearly as possible the same during each experiment. In order to obtain this every care should be taken in arranging the installation. Firstly, the current which is going to the primary coil must be kept as nearly as possible the same ; the volt and ampere meters should be watched, and the slightest variation in readings immediately corrected by the variable rheostat. Secondly, the discharge rods should be approximated and withdrawn until the exact distance between the two is found which will excite the Crookes' tube. This is of great advantage in saving the tubes, because the slightest increase in the vacuum causes sparking across the gap between the discharge rods. Thirdly, the same state of the coil should be preserved throughout the experiments, no change being made by way of alteration in the condensers or other parts in the base. Fourthly, by means of a mechanical interrupter, as described above, one can regulate the number of contacts per second by counting the revolutions of the wheel. Moreover, as we have said, by adjusting the studs on the vertical arms, we have a register of the exact time during which the current is actually passing through the primary coil. This is an advantage of the mechanical interrupter which cannot be got by any spring arrangement. Fifthly, the condition of the tube should be most carefully regulated ; and, after getting the desired excitation, a current of hot air, or a spirit lamp, or a bunsen burner, or the application of a piece of tinfoil round the tube should be resorted to in order to keep the vacuum the same throughout. The Queen's tube makes this very easy, but in any case the actinometer may be employed as an extra test. The thickness of the dark covering for the plates and the proper distance between the plate or screen, object, and Crookes' tube should be carefully adjusted. It is only by keeping such factors as nearly as possible constant that a series of experimental results sufficiently good for comparison may be got. Figure 14

**Arrange-  
ment of  
Apparatus.**



FOREIGN BODIES.—HALFPENNY IN OESOPHAGUS.

Case of Dr. Rutherford, referred to in Presidential Address by Lord Lister, Brit. Assoc., 1896.



shows how the parts may be arranged with different switches at the right of the coil, so that one may introduce the mechanical, mercury, spring, or any other interrupter at will.

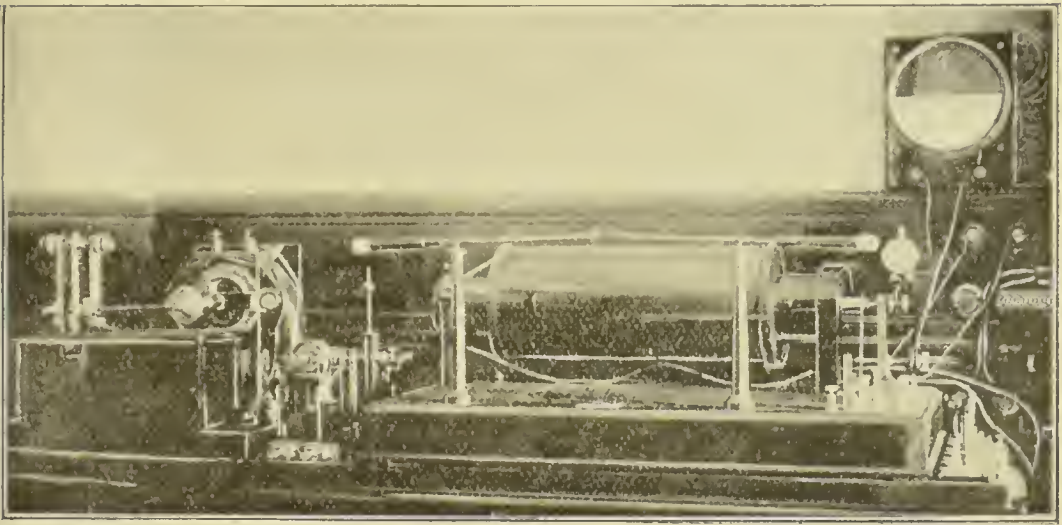


FIG. 14.—INTERRUPTER, COIL, ETC., WITH VOLT AND AMPERE METERS.

### RESULTS.

As already indicated, the apparatus required for the production of X rays was added to the electrical installation of the Glasgow Royal Infirmary in the month of March, 1896. Earlier experiments had, how-

#### General.

ever, been performed with a view to proving the value of the new agent or otherwise. The managers cordially co-operated in making the necessary arrangements, and from then until now the X rays have been constantly used in the house, although more in the surgical than the medical department. The most of the work accomplished in the former department has been undertaken by Dr. Faulds, while the medical has been looked after by Dr. George M'Intyre. As a rule, it may be stated that permanent and more valuable results have been obtained from the photographic plate; but as the fluorescent screen has become better known, a fair and important share of the work of diagnosis has been carried on by the latter. It naturally follows also that, in the first instance, the work was mostly confined to the detection of



the presence of foreign bodies. Then followed one of its best and widest uses, viz. the detection of the true lesions in dislocations and fractures. As we often find in other branches of science, comparatively little difficulty was experienced in attaining certain advances, but after a point the difficulties increased very much. While advances in methods made rapid strides for the first few months, every additional step of late has been made with greater expenditure of time and energy. This fact applies more particularly to the differentiation of the soft tissues in the adult subject. It may be interesting to note, however, that as early as the first week in March, 1896, the fluorescent screen was being used for diagnosis of minor lesions in the extremities. On the 16th March foreign bodies in the skull of a dead subject had been distinctly seen, and the spine in the living adult subject had been photographed, the plate distinctly though faintly revealing the presence of the heart as well. On the same date well-defined shadows of the bones of the upper extremities, and most of the bones of the lower extremities, had been seen. In the same week a fluorescent screen, to be placed inside of the mouth, and intended for examination of the larynx, neck, face, and bones of the hyoid, had been employed, and photographs distinctly indicating the position of the cardiac area had been obtained. On the 26th of the same month shadows of the spinal column, ribs, and thorax were well seen on the fluorescent screen, and it is interesting also to note that during this week movements, which clearly indicated the cardiac area, were observed. Foreign bodies were detected in the thoracic cavity in the first week in April, 1896; and, on the twelfth day of the same month, the first *instantaneous* photograph of the bones of the hand was obtained. During the latter period our attention was directed to the soft tissues of the body; and although shadows of the cardiac area had been previously photographed, and the movements in that region detected, the first well-defined indications of the cardiac area were obtained early in the first week in May. By then alterations in the cardiac area were not only detected by means of photography, but their shadows were also observed on the fluorescent screen. Some

of the soft tissues had been seen and photographed a considerable time before this. For example, photographs of the neck showing the hyoid bone, epiglottis, arytenoid cartilages, opening of the oesophagus and spine had been shown at the British Rhinological and Otological Association in London on the 4th April. Early in July a case of renal calculus was detected, and afterwards successfully operated upon by Dr. James Adams. About this time a really successful series of photographs of the pelvic region had been obtained, including hip joint disease. In the early part of 1897 the advances in photography had enabled us to have a series of cinematographic records of the movements of some of the lower animals, such as the frog's legs, and this, when thrown upon the screen by means of the magic lantern, showed the internal movements. It will be quite impossible, however, to do more than indicate some of the important groups of affections in which the rays have been employed in this hospital.

A large number of cases have been examined for foreign bodies. Naturally most of these have been in the extremities, and the commonest objects have been pieces of glass, needles, coins, and a few bullets or pellets in gunshot wounds. While the majority of these foreign bodies have been detected in the extremities, examples have also been obtained in the skull, thorax, and abdomen, the last region least frequently of all. In the report of cases which have come under the care of Dr. Faulds, he includes foreign bodies in the skull. I have detected a piece of metal tube in the antrum of Highmore, more than one pin in the region of the larynx, while a most interesting photograph of a case under the care of Dr. Rutherford, taken in April, 1896, is reproduced here, and was referred to by Lord Lister in his presidential address to the British Association. The shadow of this coin was seen by means of the fluorescent screen, but a photograph was also obtained. A similar case of coin in the oesophagus was recorded subsequently by Dr. Faulds, and successively operated upon by Professor H. E. Clark.

**Foreign  
Bodies.**

A very large number of these have naturally been examined by means of the X rays. Diagnosis has in many cases been confirmed; in others, mistakes relating to dislocation and frac-

tures have been corrected. Many photographs of these lesions in the extremities have been obtained, but others less common have been noted, such as fracture of the upper jaw due to a crush, a case which came under the care of Mr. Pringle. In some instances the rays have been useful in detecting the position of bone during repair, as in one of the earliest cases in which the position of the two ends of the radius, sutured by Dr. Barlow, was determined. Useful instances of diagnosis in the region of the hip have been noted. An extremely interesting point in such cases was seen on examination of the injured side. The shortening, which was very great in the young man's case, was clearly due to the dwarfing of the right side of the pelvis and femur. Examination of the healthy side will show the cartilaginous structures still in existence and providing for growth, while on the other development had been arrested.

In a few instances I have been able to note caries in the cervical region. In one case (Dr. Rutherford's) a swelling of the foot was clearly shown to be due to the cartilaginous growth, a point of interest in diagnosis. Dr. George M'Intyre has put on record changes in chronic pulmonary osteo-arthritis, the case being under the care of Mr. Lindsay Steven, and in more than one case the rays have by photography shown some interesting details in cases under Dr. M'Vail of rheumatic arthritis.

It is particularly my desire in this *résumé* to point out the lesions and regions in which it might be fairly claimed that the Röntgen rays have taught us what could not have been otherwise known without its aid, and in all fairness we might also include conditions in which corroborative evidence has been obtained by means of the rays. As far as we have gone, therefore, speaking of foreign bodies and alterations in the hard structures, I think our experience has been like that of many others, sufficient to justify the statement that in these situations and in the regions indicated we may safely make the claim. In what is to follow, however, the case is more difficult to state with all fairness. To begin with, I frankly admit that in the vast majority of medical as opposed to



FOREIGN BODIES.—HALF-SOVEREIGN IN RIGHT LUNG.





surgical cases, and where the soft tissues are involved, whatever may be our ideas of promise in the future, much remains to be done. For the most part, I think it fair to state that limited information has been obtained which would not have been got or inferred by other means of diagnosis. The most that can be said is that corroborative or supplemental evidence has been obtained. I am quite well aware that others have claimed more than this. For example, Dr. Walsh, in the *Röntgen Rays* for 1897, quotes Dr. Coupland's case, the words being, "in a case of deep aneurysm of the chest, the diagnosis was cleared up by the fluoroscope." Dr. Schott, whose work is well known in the treatment in cardiac affections, in the early part of 1896 communicated with me with a view to obtaining information of the methods adopted in photographing the heart, and I understand he now claims that important results have been obtained in diagnosis. Although I have since communicated with him asking for information, I am not in a position to say anything, as promised communications have not yet come to hand. Under my own observation, I may say, however, that I have got some information as to the exact destruction of bone in the upper jaw, caused by the advancing malignant disease. I have photographed and seen as shadows enlargements of both ventricles in a case of acute pneumonia, the first photograph being one of a case under the care of Dr. M'Vail. I have also distinctly seen on the screen and photographed enlargements of both ventricles of the heart, while searching for a case of pressure in the recurrent laryngeal nerves. I have obtained photographs and seen shadows of aneurysm within the thorax.

Speaking more particularly of the thoracic region, in a number of cases the borders of the heart are well defined on the screen, and movement can be made out. This is not sufficiently definite to make out all the movements of the different parts of the heart. The aorta can in many cases be very well seen, and less frequently the border of the right auricle.

The diaphragmatic movements are interesting both in health and in disease. For example, the structures may be seen

pushed upwards where there is pressure in the abdomen, and limitation in the descent of the diaphragm may be made out where the lungs are not fully expanded, and this from different causes. The rapidity of the movement of the diaphragm can easily be detected, and even irregularities in its action may occasionally be observed on the screen.

In the region of the abdomen, like other workers, I have experienced the greatest difficulty. The most interesting case is that above mentioned, in which a phosphatic mass in the kidney was detected and afterwards operated upon by Dr. James Adams. I have, however, failed completely in one instance where the surgeon afterwards operated and found a renal calculus. I may say, however, that my own work in the hospital is altogether in connection with diseases of the nose and throat, and consequently I have had little opportunity, unless when called upon to give assistance to some of my colleagues, of exploring or examining the abdominal cavity. Lest any of these remarks should be misleading to others who may be interested in this particular work, I repeat that my personal experience has been altogether by way of corroboration, and most of the lesions could have been inferred by other methods of diagnoses.

In conclusion, I should like to say that our experimental and routine work in the hospital has been singularly free from injuries. In my own case, as reported in the *Lancet*, a slight dermatitis ensued, but that was after working for nights in succession with the left hand in front of the X ray tube. At present we are undertaking a series of experiments in the hope of showing what actually is the dangerous condition of the tube, electrical or otherwise, which has caused such a lesion to be put on record. We have also undertaken a considerable number of experiments as published in *Nature*, with a view to obtaining any indications of polarization, refraction, or reflection, the aim of such work being easily understood by those who really appreciate the great advance that would follow the discovery of any such means. As yet the results have been purely negative. Notwithstanding these disadvantages, efforts are continually being made to obtain better results from improved apparatus, familiarly with the appearances of lesions



EXPERIMENTS IN DEEP STRUCTURES.—FIRST PHOTO OF PELVIS  
SHOWING OLD DISEASE OF HIP JOINT.





on the screen, and, last of all, by comparative results of the transformers, particularly the relationship between the influence machine and the coil. While there is much yet to be done, it may be fairly claimed that the results in a certain number of cases have thoroughly justified the managers in establishing and equipping this special department in the hospital.

#### NOTE.

A few reproductions of photographs are interleaved, mainly with a view to showing the first which were obtained of the hard and soft tissues at the periods indicated in the paper.







